DISCUSSION PAPER

FOR

AN INTERNATIONAL UPLAND CROPS PROGRAM

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AN INTERNATIONAL CROPS PROGRAM

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The writer expresses his appreciation to the Asian leaders and scientists who participated in an informal meeting on the problems of improving upland crops in Asia, and to members of the Rockefeller and Ford Foundations, the International Development Research Center, the Food and Agricultural Organization of the United Nations and the International Rice Research Institute.

AN INTERNATIONAL UPLAND CROPS PROGRAM

SUMMARY

Increased productivity of upland crops can help alleviate mounting problems of food, income, and employment. In highly-populated, developing nations, the establishment of profitable agricultural systems must be accorded high priority. Moreover, they must be appropriately adapted and specially designed to fully utilize the human and natural resources of the area. This means that the rainfed, unirrigated, upland regions with prolonged dry periods which have been largely bypassed by contemporary yield-increasing technologies, be better integrated into future calculations for improving food resources. Although [redacted] nations are undertaking programs to improve crop production, prospects are that these largely uncoordinated, and inadequately supported programs will not respond in time to meet accelerating needs. The odds are against them.

The imperative problems of food, population and unemployment demand that the odds be improved; that more favorable solutions be arranged. International institutes to provide training and channel reliable information and improved technology into viable national programs could do just that - tilt the balance in favor of success.

To assist developing nations improve crop productivity and output in tropical upland regions, it is recommended:

1. that a detailed proposal be prepared for an international upland crops institute to be established in Asia. Such an institute to serve as (a) a center to develop and demonstrate improved cropping patterns and systems of farming which optimize the use of human and natural resources in low-rainfall, unirrigated, upland tropics, and (b) a world research center for improvement of sorghum, millets, chick-peas and pigeon peas;
2. that the International Rice Research Institute be requested to analyze the feasibility of expanding its program to include upland rice and crops grown in the high-rainfall, seasonally-dry, undulating to rolling tropical uplands;

3. that the International Maize and Wheat Improvement Center be requested to analyze the feasibility of expanding its work to include wheat grown in low-rainfall, unirrigated, low-latitude areas.

Nations would benefit in several ways. The international institutes would develop, maintain and make available services and research materials not generally available in individual countries, and which would be beyond strictly national capabilities, especially those with pressing food and population imbalances. Through the solution of soil, water and crop problems constraining productivity, the institutes would generate useful technology while demonstrating methods and techniques which could be used to significantly increment upland crop production.

DISCUSSION PAPER FOR AN INTERNATIONAL UPLAND CROPS PROGRAM

BACKGROUND

As a result of discussions at Bellagio in April 1970, the Foundations agreed to look into the need for an international institute for "upland crops"[1] with special concern for the unirrigated, rainfed, highly populated regions of Asia.

The matter has been investigated. Discussions have been held within the Foundations, with representatives of international agencies and selected Asian nations, and with knowledgeable scientists and agricultural leaders.[2] From the discussions it is clear that while there have been impressive gains in wheat and rice production, a large production problem still exists in Asia because of the increased need for food by burgeoning populations. The innovations which are revolutionizing crop production in areas where water is not limiting have had little applicability and relevance in the unirrigated, rainfed uplands. Vast rainfed agricultural areas in Asia and other parts of the tropical world have been largely bypassed by contemporary yield-increasing technologies. As a result, there is mounting concern throughout Asia over the consequences of the uneven spread and usefulness of present crop improvement technologies. Without exception, persons contacted agreed that a special need exists to improve the productivity of crops in tropical upland areas, and especially in the difficult, low and uncertain rainfall regions.

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[1] In the tropics, crops grown in higher, non-flooded, rainfed areas are commonly referred to as "upland crops" in contrast to rice grown in the flooded lowlands.

[2] See Appendix 2 for a list of persons consulted and meetings held.

MAJOR CONSIDERATIONS AND FACTORS INFLUENCING AN INTERNATIONAL EFFORT TO IMPROVE UPLAND CROPS

The area of need

The primary need for increased production of upland crops, is centered in the tropics, particularly in Asia where the stress of adverse ratios of population, food and low agricultural productivity is most acute. The FAO's Indicative World Plan reports that the demand for food in developing countries (practically all of which are located in the tropics) by 1985 is likely to be two and one half times what it was in 1962. For most of Asia and parts of Africa, "agricultural intensification and the use of modern technology to raise productivity per unit of cultivated land must therefore be looked upon as an imperative for survival."[3] Thus, for this discussion tropical Asia and Africa are the target areas for increasing the production of upland crops.[4]

Tropical climates and upland crops

While there is an almost infinite variety of local rainfall patterns in the tropics, classification of tropical climates (and agroclimatic zones) can be made on the basis of broad rainfall groups. Such a classification has been made by Professor C. Troll, Director of the Institute of Geography of the University of Bonn.[5] Troll's classification describes the following for the tropics:

V. Tropical Zone

1. Tropical rainy climates with and without short interruptions of the rainy season (12 to 9-1/2 months): evergreen tropical rain forest and half-deciduous transition wood.

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[3] Provisional Indicative World Plan for Agricultural Development, Vol. I, FAO, Rome, 1969, p. 89.

[4] See Appendix 3 for a comparison of population and land resources.

[5] Troll, C., "Seasonal Climates of the Earth," in Rodenwaldt, E. and Jusatz, H., eds., World Maps of Climatology, Berlin, Springer-Verlag, 1965, p. 28.

2. Tropical humid-summer climates with 9-1/2 to 7 humid and 2-1/2 to 5 arid months: rain-green forest and humid grass-savannah.

2a. Tropical winter-humid climates with 9-1/2 to 7 humid and 2-1/2 to 5 months: half deciduous transition wood.

3. Wet and dry tropical climates with 7 to 4-1/2 humid and 5 to 7-1/2 arid months: rainy-green dry wood and dry savannah.

4. Tropical dry climates with 4-1/2 to 2 humid and 7-1/2 to 10 arid months: tropical thorn-succulent wood and savannah.

4a. Tropical dry climates with humid months in winter.

5. Tropical semi-desert and desert climates with less than 2 humid and more than 10 arid months: tropical semi-deserts and deserts.

The distribution of the above climates is shown on the map in Appendix 1. Troll's classification and map of seasonal climates is useful for agronomic purposes and for assessing the magnitudes of areas in the several climatic regions. Recently, his data have been adapted and used for analyzing the resources and agricultural potentials of the tropics and other areas of the world.[6] Table 1 estimates the amounts of potentially arable land in tropical climate types by continents.

If Troll's classification is divided into two groups, those in V1 and V2 climates and those in V3 and V4 climates, then these can be separately categorized, the former as humid for most of the year (7 months or more) and the latter arid for extended, if not most, of the year (7 months or less). While such a categorization of climates is arbitrary and not perfect, it makes the important point that there are at <u>least two different agroclimatic situations</u> with respect to crop production in the tropics. The moisture supply and associated conditions for crop production in these two situations are sufficiently different as to require different crops and systems of farming. Thus, plans and programs for upland crop improvement should be based on the requirements of the major agroclimatic areas.

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[6] <u>The World Food Problem</u>, Report of the Panel on the World Food Supply, Vol. II, The White House, 1967. pp. 407-500.

TABLE 1

Potentially arable land[1] in tropical agroclimatic regions by continents[2]

Agroclimatic region			Potentially Arable Land 10^8 acres				
Climate type	Months: Humid	Months: Dry	Africa	Asia	Australia	North America	South America
V1 Rainy	9 1/2-12	0-2 1/2	2.7	2.0	---	0.3	7.5
V2 Humid seasonal	7-9 1/2	2 1/2-5	5.5	3.1	0.1	0.4	4.4
V3 Wet-dry	4 1/2-7	5-7 1/2	5.1	1.9	0.3	0.5	0.3
V4 Dry	2-4 1/2	7 1/2-10	2.8	1.2	0.6	0.1	0.3
V5 Semidesert & desert	0-2	10-12	0.4	0.2	0.1	0.01	0.04
		Total	16.5	8.4	1.1	1.31	12.54

[1] Potentially arable land includes soils considered to be cultivatable and acceptably productive of food crops adapted to the environment. Some soils will need irrigation, drainage, stone removal, clearing of trees, and other measures.

[2] Adapted from data in Tables 7-8 and 8-1 in The World Food Problem, pp. 432 and 475.

In the rainy and seasonally humid V1 and V2 climates of Southeast (monsoon) Asia, rice is and will be for the foreseeable future the main food crop and principal agricultural activity for millions of small cultivators. Rice is especially adapted to the high-rainfall alluvial lowlands of the river valleys, flood plains and coastal areas. But it is also grown widely on the lower- rain-fall uplands and high terraces where moisture, soil and temperatures permit. Thus in densely populated Southeast Asia, on countless millions of small holdings, rice is the hub around which other farming operations are centered. From country to country the particular combination of crops and livestock vary, but rice is the constant in most upland V1 and V2 agroclimatic areas.

The Multiple Cropping Program at IRRI has demonstrated the potentials and opportunities for increasing productivity and output through multiple cropping systems built around rice. Though the program is relatively new and still evolving, results to date indicate great opportunities for increased food production and improved diets through intensive farming systems using rice and other crops. The demonstrated complementarity and supplementarity between rice grown in the wet season and "upland crops" grown on residual moisture in the dry season favors the building of research and training programs for the improvement of the upland crops around rice. Assuming the validity of this viewpoint, there is strong justification that upland crop programs in V1 and V2 areas should be conducted in close association, perhaps jointly with rice research programs.[7]

Dry climates (2 to 4-1/2 months humid) are found extensively in Asia, Africa and Australia (Table 1). Based on experiences of rather productive, extensive-type, farming systems developed in Australia and the United States, tropical dry areas are considered to possess varying potentials for increased crop and livestock production. However, whether sustained, economic increases can be achieved in the more highly populated, undeveloped areas of Asia and Africa, without mechanization and engineering, is conjectural and requires investigation.

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[7] See Appendix 4 for a statement by the distinguished agronomist, Dr. Richard Bradfield.

The rainfall limit for dryland farming in most tropical areas is about 240 mm/yr (10") precipitation. Above this lower precipitation limit and below that of the humid regions, perhaps in the 15" to 35" range where the moisture supply is adequate for cropping for two to four or five months, there are millions of acres of arable lands devoted to primitive agricultural systems using unimproved crops, inefficient tools and equipment, and inadequate power. It is believed that such lands offer reasonably promising prospects for increasing productivity through the use of improved crops and livestock, more efficient means of using and manipulating soils and conserving moisture. The map of tropical climates in Appendix 1 gives the distribution of such areas (V4 type climates, overlapping somewhat into V3 and V5 climate areas). Appendix 5 lists most countries having significant areas of V4 climate.

Tropical crops

Agroclimatic conditions in tropical regions provide for the production of a wide variety of cereal, food legume, oil, tuber, fiber, sugar, vegetable, fruit and plantation/commercial crops. Appendix 10 gives a partial list of the more important ones.[7a]

Important crops in the high-rainfall V1 and V2 areas are rice (paddy), maize, casava, sweet potatoes and yams, coconut, oil palm, sugarcane and local food legumes (e.g., cowpeas, black gram, mung beans). Crops of the rainfed V3 and V4 areas are mainly sorghum, millets, wheat, groundnuts, cotton and local food legumes such as chick-peas and pigeon peas. In terms of acres of production, the important crops of the tropics closely parallel the world's major crops shown in Table 2.

[7a]Extensive acreages in the tropics are used to produce plantation crops such as tea, coffee, rubber and oilcrops, and commercial crops such as cotton, sugarcane and jute. These important crops, the research and improvement of which are generally adequately taken care of by commercial interests and state enterprises, are not included in this discussion.

TABLE 2

World's Major Crops - 1968*

CROPS	WORLD AREA (millions of hectares)
Wheat	227.5
Rice - Paddy	132.2
Total Oilseeds[a]	112.6
Millets and Sorghum	111.2
(Millets)	(33.9)
(Sorghum)	(37.5)
(Unspecified Millets and Sorghum)	(39.8)
Maize	106.0
Barley	74.9
Total Pulses[b] (Food Legumes)	62.7
Oats	32.3
Cotton	31.6
Potatoes	22.8
Rye	22.4
Sweet Potatoes and Yams	16.0

[a] Soybeans, groundnuts, cottonseed, linseed, rapeseed, sesame seed, sunflower seed, and castor beans.

[b] Dry beans, dry peas, dry broad beans, chick-peas, lentils, pigeon peas, cowpeas, vetch, lupins and miscellaneous.

* Source: FAO Production Yearbook, Vol. 23, 1969.

The largest and, perhaps, the most extensively cultivated V3 and V4 areas in South Asia occur in India. Sorghum and pearl millet (Pennisetum typhoides) are the most important unirrigated, rainfed crops in such areas. This is shown in the results of a survey of cropping patterns in 84 low-rainfall (400 to 1,000 mm. annually), largely unirrigated districts.[8] While a few of the districts, such as those in Jammu and Kashmir, are not in V3 and V4 areas, most of them are. The results are shown in Table 3. The data clearly show that sorghum, millets, groundnuts, cotton, wheat and chick-peas are the most important crops in typical low-rainfall, unirrigated areas of India. The data underscore the national importance of particular crops grown in such areas: for groundnuts, sorghum, cotton, pigeon peas and wheat, the percentages of the All-India (national) acreages are 74.06, 64.34, 60.51, 47.24 and 30.66, respectively.

The survey also reveals that a relatively larger fraction of the land area is cultivated in low rainfall, unirrigated areas than in cultivated for the country as a whole as shown in the All-India figures: 57.16 percent of the total geographic area in the sampled districts as against 46.64 percent of the country as a whole.[9] This suggests that for various reasons, e.g., population pressure, cultivation has been extended to marginal and submarginal lands.

Adequacy of present crop technology

A cursory, but reasonably accurate, review of the state of present knowledge for increased farm production of the major tropical food and feed crops grown in the tropics shows serious gaps and deficiencies in production technology.[10] A reasonably adequate situation prevails with respect to irrigated wheat, maize and rice; although there are still shortcomings, knowledge and materials are available for rapidly expanding the production of these cereals under controlled irrigation. Beyond the relatively strong

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[8] A New Technology for Dryland Farming. Indian Agricultural Research Institute, New Delhi, India, 1970. 189 pp.

[9] A New Technology for Dryland Farming, Op. Cit. p.5

[10] See Appendix 6.

TABLE 3

Cropping pattern in the low rainfall-unirrigated areas
(average of 84 districts)[a]

CROPS	Area under different crops in percentage of total cropped area		Proportion of All-India acreage (in percent)
	Low rainfall unirrigated areas	All-India	
Jowar (Sorghum vulgare)	22.92	11.92	64.34
Bajra (Pennisetum typhoides)	11.61	7.56	51.39
Maize (Zea mays)	1.62	2.93	19.19
Ragi (Eleusine coracana)	2.35	1.69	46.33
Wheat (Triticum aestivum and Triticum vulgare)	7.66	8.36	30.66
Barley (Hordeum vulgare)	1.40	2.20	21.38
Gram (Cicer arietinum)[b]	6.27	6.66	31.51
Arhar (Cajanus cajan)[c]	2.33	1.65	47.24
Groundnut (Arachis hypogaea)	9.17	4.15	74.06
Other oilseeds	3.31	3.30	36.52
Cotton (Gossypium arboreum, G. herbaceum and G. hirsutum)	9.55	5.28	60.51
Other crops	21.81	44.40	-
Totals	100.00	100.00	

[a] India. Taken from A New Technology for Dryland Farming, op. cit., p. 7.

[b] Chick-peas

[c] Pigeon peas

position of these crops under highly favorable conditions, prospects are bleak for more than modest increases of other crops in the tropics. This is especially true of tropical crops grown under difficult conditions. For the sorghum and millets, which are grown generally under conditions of moisture stress, there are major deficiencies in production technology. Similarly, other major tropical crops are as yet untouched by modern technologies and will remain so until appropriate research is undertaken. Table 4 which provides a comparison of average yields of selected major crops by regions shows the low average yields in Asia and Africa. These data reflect, in part, the inadequate state of tropical crop production technology.

Crop research of existing international institutes

Listed in Table 5 are the present international research centers, their crops and the principal agroclimatic regions they serve. Comparison of the crops of centers with the world's major crops listed in Table 2 shows that sorghum and millets are the only major tropical crops for which there is no international research center. An estimated 400 million people eat sorghum or millets as a staple food.[11] Thus, their importance as a food crop in Asia (principally India and Pakistan) and Africa, and their total acreage, constitute a visible challenge.

Other generally neglected crops are the food legumes (pulses) which are important protein sources to millions of people. In Asia where there are large numbers of vegetarians and where animal proteins are scarce, the pulses are especially valuable foods and warrant greater attention for improvement.

Tropical soils

The question of the amount and suitability of tropical soils for upland crops production is significant. Table 6 gives estimates of the extent of the major soil groups found in the tropics and estimates of potentially arable areas.[12] Most soils in the tropics, except alluvial soils of the river

[11]See Appendix 7, paragraph A2.

[12]The World Food Problem, Op. Cit., p. 483.

TABLE 4

Yields of selected crops in metric tons per hectare by continents - 1968*

CROP	World	Europe	North & Central America	South America	Asia	Africa
Wheat	1.46	2.53	1.78	1.03	1.07	1.02
Rice (paddy)	2.15	4.15	3.81	1.67	1.89	1.92
Millets and Sorghum	0.77	2.73	3.05	1.52	0.48	0.66
Maize	2.37	2.92	3.78	1.43	1.10	1.08
Potatoes	13.80	18.70	22.00	7.60	10.80	7.00
Groundnuts	0.82	1.57	1.82	1.14	0.70	0.80
Sweet Potatoes and Yams	8.40	14.20	6.60	10.70	9.40	7.10

* Production Yearbook, Vol. 23, 1969, FAO.

TABLE 5

PRESENT INTERNATIONAL INSTITUTES

CENTER	CROPS	AGROCLIMATIC AREA
CIMMYT*	Wheat Corn Potatoes	Adequate Rainfall & Irrigated Areas Temperate - Tropical
IRRI*	Rice (paddy) Multiple Cropping	Adequate Rainfall & Irrigated Areas Subtropical - Tropical
CIAT*	Rice Corn Beans (*Phaseolus vulgaris*) Cassava Forages (tropical grasses and legumes)	Adequate Rainfall & Irrigated Areas Low Tropics
IITA*	Corn Cowpeas Sorghum Rice Root Crops Forages (tropical grasses and legumes) Vegetables	Adequate Rainfall & Irrigated Areas Low Tropics

* CIMMYT - Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center), Mexico City, Mexico.

IRRI - International Rice Research Institute, Los Baños, The Philippines.

CIAT - Centro Internacional de Agricultura Tropical (International Center of Tropical Agriculture), Cali, Colombia.

IITA - International Institute of Tropical Agriculture, Ibadan, Nigeria.

TABLE 6

Total acreage by continents of different soil groups in the tropical zone and estimates of the areas potentially arable and potentially available for grazing

(Millions of acres)

Soil Groups	Africa			Asia			Latin America			Australia and New Zealand			Total	Total arable[1]	Total grazing
	Total	Arable[1]	Grazing	Total	Arable[1]	Grazing	Total	Arable[1]	Grazing	Total	Arable[1]	Grazing			
1. Light-colored soils; base rich----------	1,128	[2] 160	300	200	[2] 80	40	204	[2] 50	80	191	[2] 40	50	1,723	[2] 330	470
2. Dark-colored soils; base rich----------	267	140	30	134	60	10	260	125	40	61	20	10	722	345	90
3. Moderately weathered and leached soils--	40	20	10	211	135	45	197	15	80	68	20	10	516	190	145
4. Highly weathered and leached soils------	2,437	1,200	500	1,220	270	660	2,514	1,135	180	100	40	30	6,271	2,645	1,370
5. Shallow soils and sands--------------	1,165	90	300	283	30	100	380	40	150	259	30	50	2,087	190	600
6. Alluvial soils------	198	105	15	420	285	50	295	40	190	-----	-----	-----	913	430	255
Total----------	5,235	1,715	1,155	2,468	860	905	3,850	1,405	720	679	150	150	12,232	4,130	2,930

[1] Under technology equivalent to that of the United States.

[2] Assumes application of irrigation water.

Source: The World Food Problem, p. 483.

valleys and flood plains, are "problem" soils which require careful management. Some, especially in the high-rainfall areas, are high-weathered, strongly acid and low in plant nutrients. Others have high inherent fertility but have poor physical condition and are difficult to till. In the low-rainfall regions, alkalinity, droughtiness and low nitrogen are problems. These examples are illustrative of a wide range of soil problems found in tropical areas. However, the soils of the tropics, when treated with special attention, are considered to have potential for sustained, intensive agricultural production.

It is, by now, axiomatic that plans for intensive, continuous cultivation of tropical soils using high-yielding, soil-depleting row crops should be accompanied by research to follow and measure the soil changes which take place under varying systems of management. The development of soil conserving, fertility and tilth-maintaining practices is vital. To ensure generation of information for the maintenance of the soils base for permanently productive agricultural systems in disparate tropical regions, <u>appropriate soils research is required in representative agroclimatic zones</u>.[12a]

It should be noted that the most populous nation in South Asia, India, has a favorable soils base for increasing crop production. Russell and Brinegar, after reviewing India's natural resources for crop production, concluded that the soils in India's major cropping regions, if properly managed, especially for water storage, are capable of supporting much higher levels of production.[13] Specifically, they suggest that the alluvial, black, and red & laterite soils which cover more than 75 percent of India are capable of production increases 5 to 10 times above current levels (given greater storage of water in soil profiles and underlying aquifers, better management and use of exogenous stream and canal flow, use of proven production technology, suitable techniques for tillage and timely seedbed preparation, incentive prices, etc.).

[12a] Thus, by inference, agronomic research at <u>one center</u> could not encompass the variety and complexities in local tropical agricultural situations.

[13] Russell, M. B. and Brinegar, G. K., <u>The Development and Adoption of Production Technology</u>, a report prepared for USAID, New Delhi, India, April 1969.

Prospects and needs for improving upland crop production

A central question is whether an international effort to increase productivity in the low-rainfall tropics is justified. In terms of the need for better human nutrition and increased incomes for capital formation in developing nations, there appears to be no question that the effort should be made.

Two questions now become apparent: whether there are other more promising and rewarding ways of meeting the problems of food and income in areas where the water supply may seriously limit crop production; and on the other hand, whether better development and management of climate and soil resources coupled with greater use of existing technology, will yield economic increases which will justify an international effort. A brief analysis of some relevant factors will help in exploring possible answers. As in more favorable environments, the cereals - dryland wheat, sorghum and millets - probably offer the best cropping opportunities for rapid increases in agricultural productivity in the low-rainfall tropics (V3 and V4 climatic areas). This conclusion is primarily supported by evidence of traditional planting, as principal crops, in these areas; and to a degree, on corroborating research which has been accumulating on these cereals. In the case of wheat, there is a considerable reservoir of knowledge and materials upon which to draw. Further, there is an international wheat center (CIMMYT) with strong support ties into a number of national programs representing a wide variety of climatic conditions. Through CIMMYT, research for wheat grown in low-rainfall tropical areas could be accelerated rapidly.

Less work has been done on tropical sorghum and millets, but promising research programs are getting underway and world collections of these crops are being assembled and screened. Use of cytoplasmic male-sterility techniques for producing hybrid sorghum seed has made possible the wide use of high-yielding sorghum hybrids.[14] Several Indian sorghum and millet hybrids outyield local varieties several times and demonstrate that large food increases through these crops are within reach. However, problems of grain quality for human consumption, susceptibility to diseases and insects,

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[14] See Appendix 8 for comments on the usefulness of sorghum and millets and a listing of selected programs in the world.

climatic adaptability, particularly in the rabi (winter) season, have slowed the spread of these hybrids in India. Nevertheless, the yield potentials for increases in food and feed in dry tropics through sorghum and millets do exist; such increases would probably not be of the same order as in the United States,[14a] but certainly could be in the order of 100 to 200 percent. Present extensive acreages of sorghum in dry tropical regions which produce very low average yields suggest the tremendous scope for increased future production.[15]

In the tropical areas where sorghum and millets are grown agricultural activities are mixed, with unintensive systems of crop and livestock production occurring on relatively large land holdings in less-densely populated regions (as compared to the humid tropics). Close biological and economic interrelationships between crops and livestock require local crop (agronomic, horticultural and forest where feasible) and livestock improvement programs which must be planned and carried out together. Otherwise, the precarious biological balance between water, soils, crops and livestock could be lost and serious, possibly permanent, damage could result. Thus, at the point of implementation - the national level in smaller countries, state level in larger countries - crop and livestock improvement programs in the low-rainfall tropics should be planned and conducted jointly.

With regard to specific requirements for increasing upland crops in rainfed V3 and V4 climatic areas, there is urgent need for:

1. in-depth interdisciplinary research on sorghum, the more important millets, and probably, chick-peas and pigeon peas;
2. development work on cropping systems and related enterprises;
3. training of personnel for national programs; and
4. arrangements for international cooperation of various types which would be necessary to rapidly increase productivity of upland crops in many nations where they are important now or where they are of potential importance.

[14a] In the 15 years prior to 1965 sorghum acreages increased 71 percent and grain production more than quadrupled by 438 percent in the United States.

[15] Rachie, K. O., "Sorghum Grain: Its Worldwide Significance and Potential," Cereal Science Today, August 1979, Vol. 14, No. 8, pp. 271-276.

Summary and discussion

It is clear from consideration of climate, soils, crops and agricultural systems that at least two agroclimatic situations exist with respect to tropical upland crops and that these two situations should be treated separately. The nature of treatment and how to deliver it on an international basis is less clear. With regard to nature, precedent points to highly focused, problem-oriented lines of research on key agricultural enterprises, crop or livestock, which offer early and promising prospects for increases in productivity, as the likely avenues to success. With regard to how, the issue resolves to whether existing international institutions can be used or whether new international institutions should be created.

The rationale for new institutions is based principally on the experience of IRRI and CIMMYT, particularly IRRI where spectacular, far-reaching results have been achieved in less than a decade. The success of IRRI is attributed to the narrow problem-focus of a few talented scientists, adequately financed and supported, on one important crop without distraction and interference. There is no denying the validity of this point of view: unfettered concentration on a single important subject is apt to produce handsome technological dividends.

The main case for using existing institutes resides in well-tested experiences which demonstrate that maximum benefits accrue when improvements are made concurrently/sequentially across the range of economic activity. To ensure that improvements will be relevant to most, if not all, agricultural activities, and will not result in imbalances, research on major crop, livestock and related enterprises should be planned and carried out in close association. Safeguards can be arranged to engineer concentration of effort where needed. Also, benefits and savings gained through such multipurpose institutes often outweigh possible negative considerations.

Balanced improvement and growth of agriculture in the V1 and V2 climatic areas of Southeast Asia require increases in productivity of rice and enterprises centered around rice. For this reason expansion of the IRRI to include an activity devoted to upland crops (such as suitable varieties of soybeans, sorghum, maize, yams, and vegetables) would be a predictable course of action. Multiple cropping activity already exists at IRRI, and could be easily expanded to provide greater concentration on other crops important in the region. To do so would capitalize on IRRI's unique position, reputation and capabilities; and eventuate in savings in time and money because of the more comprehensive use of existing facilities.[16] While a great deal remains to be done in rice improvement, progress in rice research and on-the-farm production of rice is at a point where more attention should be devoted to other crops (and livestock enterprises). To the millions of subsistence farmers who do not or should not live by rice alone, this could be a tremendous boon.

Several possibilities exist in considering methods of international support to upland crops development in V3 and V4 climates. The first would be to organize and establish an international upland crops institute in Asia. Such an institute would be designed to meet the needs of the principal crops and cropping systems in Asian V3 and V4 agroclimates. Since sorghum and millets[17] are the main crops in these agroclimatic areas, the institute would serve as an international center for sorghum and millets and as a center for the development and demonstration of suitable cropping patterns and systems of farming. See Appendix 9, An International Upland Crops Institute, for broad outlines of such an institute.

If it is not possible to arrange for an upland crops institute or center in Asia, then locations in East Africa or Mexico are possible alternatives. Each has advantages and disadvantages.[18]

The establishment of an international sorghum and millets program should not preclude continuation of present sorghum and millets programs. In fact, existing programs should be stepped-up to ensure sustained, interdisciplinary attacks on important problems constraining production.

Since a number of crops grown on tropical uplands are, or will be, the subject of research concentration at existing institutes,[19] upland crop

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[16] See Appendix 4 for a more detailed statement of the rationale for expanding IRRI.

[17] Concentration would probably be limited to pearl millet, but this decision should be based on the judgment of scientists and results of a feasibility study.

[18] See Appendix 7 for a thorough discussion of possible locations for international sorghum and millets research.

[19] CIMMYT, IRRI, CIAT, and IITA.

improvement could be even further accelerated if present institutes increase their direct involvement in national programs. Current IRRI programs with the Ford and Rockefeller Foundations and USAID in India and East Pakistan are examples of the kind of effective direct support which can be arranged for national programs.

The expansion of IRRI to provide for appropriate upland crops research and training requires additional personnel, facilities and land. The exact requirements could be quickly determined. A rough estimate indicates perhaps six additional scientists/specialists; 40-50 hectares of additional land (suitable areas are available within 30-40 miles of IRRI); added office, laboratory and field equipment and buildings. Capital costs for expansion would likely be of the order of two million dollars. Annual recurring costs, exclusive of technical assistance contracts, would be in the range of $400,000 to $500,000 to start with, such costs eventually reaching $1.0 million.

Based on the experience of other international centers and considering rising costs, capital costs for a new upland crops institute are likely to be in the $12-15 million range. An important element of the total capital requirement depends on whether land would be provided by the host government.

Capital costs for the establishment of IRRI and IITA have been approximately $7.5 million and $12.0 million respectively, exclusive of lands which were provided by host governments. Expansion of facilities and services since establishment has increased these costs. In the case of IITA, capital costs are approaching $16.0 million and are apt to reach $20.0 million.

Operating costs for an upland crops institute will likely reach $1.5 million to $2.0 million-plus annually. IRRI's operating budget, which reflects a large staff and a wide range of training and other support services, is a bit over $2.0 million. In the case of IITA, still in the process of developing a range of services, the operating budget is about $1.5 million.

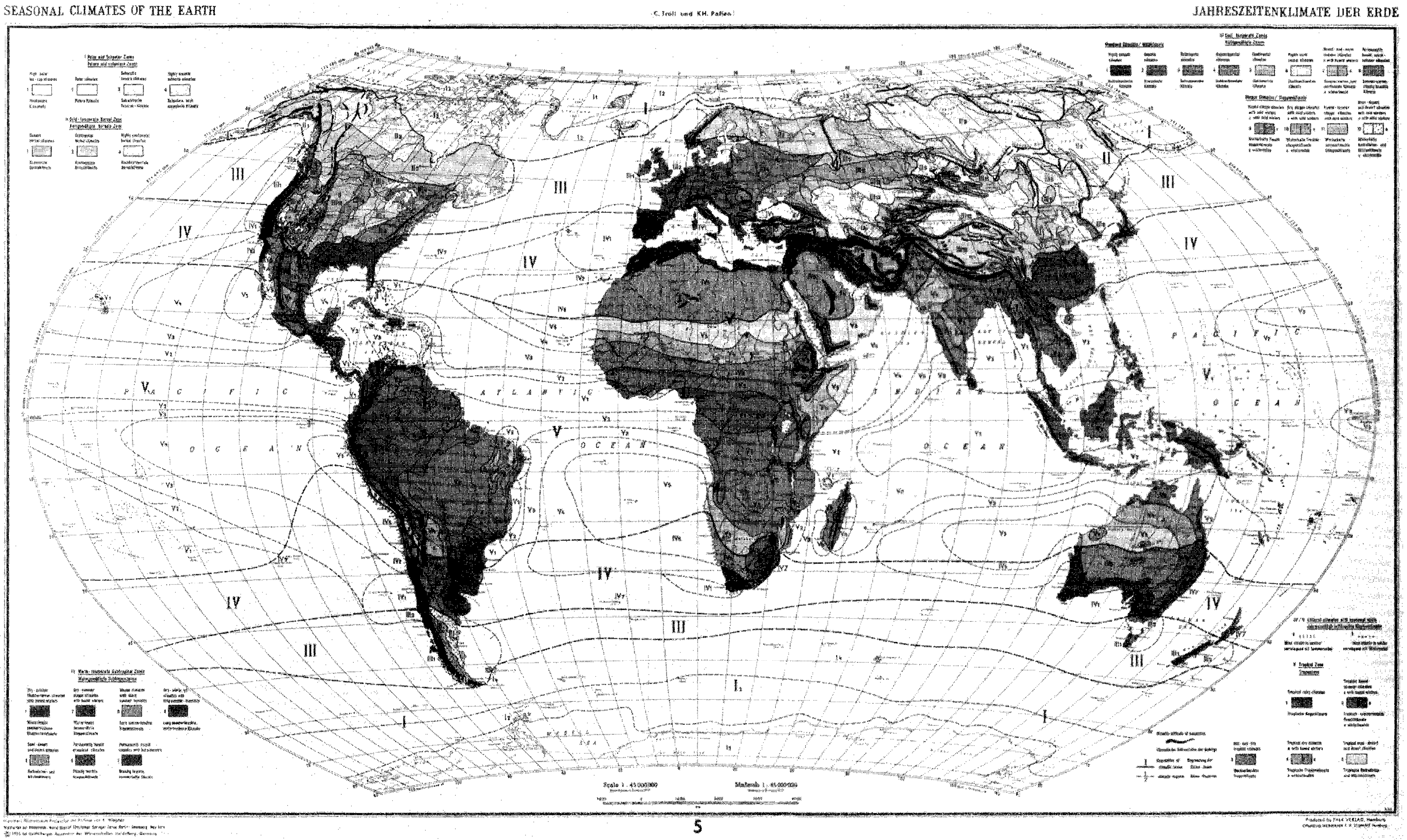
Requirements to expand CIMMYT for sorghum and millets work will likely require $400,000 to $500,000 a year to start and $1.0 to $1.2 million annually when fully operative.

RECOMMENDATIONS

To assist developing nations improve crop productivity and output in tropical upland regions, it is recommended:

1. that a detailed proposal be prepared for an international upland crops institute to be established in Asia. Such an institute to serve as (a) a center to develop and demonstrate improved cropping patterns and systems of farming which optimize the use of human and natural resources in low-rainfall, unirrigated, upland tropics, and (b) a world research center for improvement of sorghum, millets, chick-peas and pigeon peas;
2. that the International Rice Research Institute be requested to analyze the feasibility of expanding its program to include upland rice and crops grown in the high-rainfall, seasonally-dry, undulating to rolling tropical uplands;
3. that the International Maize and Wheat Improvement Center be requested to analyze the feasibility of expanding its work to include wheat grown in low-rainfall, unirrigated, low-latitude areas.

APPENDIX 1



H.E. Landsberg, H. Lippmann, Kh. Paffen, and C. Troll, World Maps of Climatology, edited by E. Rodenwaldt and H. J. Jusatz, Springer-Verlag, New York, 1965, 2nd edition. (Reproduced through the courtesy of the publisher.)

APPENDIX 2

PERSONS CONSULTED WITH REGARD TO AN INTERNATIONAL UPLAND CROPS PROGRAM

1. The Ford and Rockefeller Foundations held several meetings to discuss papers being prepared for the Bellagio group. Meetings were held in New York on July 21 and 22 and October 12 and 13, 1970. Persons participating are listed below:

Name	Title	Organization
Dr. David E. Bell	Vice President	Ford Foundation
Dr. F. F. Hill	Program Advisor	Ford Foundation
Dr. Lowell S. Hardin	Program Officer	Ford Foundation
Dr. Edgar O. Edwards	Program Advisor	Ford Foundation
Mr. Paul A. Strasburg	Assistant Program Officer	Ford Foundation
Dr. Nathan M. Koffsky	Consultant	Ford Foundation
Dr. A. T. Mosher	President	Agricultural Development Council
Dr. W. D. Hopper	President	International Development Research Centre
Dr. Sterling Wortman	Director Agricultural Sciences	Rockefeller Foundation
Dr. Ralph W. Richardson	Deputy Director Agricultural Sciences	Rockefeller Foundation
Dr. Lewis M. Roberts	Associate Director Agricultural Sciences	Rockefeller Foundation
Dr. Clarence C. Gray, III	Associate Director Agricultural Sciences	Rockefeller Foundation
Dr. John A. Pino	Associate Director Agricultural Sciences	Rockefeller Foundation
Dr. John J. McKelvey, Jr.	Associate Director Agricultural Sciences	Rockefeller Foundation
Dr. R. K. Davidson	Deputy Director Social Sciences	Rockefeller Foundation

Name	Title	Organization
Dr. M. P. Todaro	Assistant Director Social Sciences	Rockefeller Foundation
Mr. Ellis Hatt	Consultant	Ford Foundation

2. On August 20 and 21, 1970, The Rockefeller Foundation sponsored an informal meeting of Asian agricultural leaders and scientists to discuss the upland crops situation in Southeast Asia. Participants were:

Name	Title	Country/Program
Dr. Phit Panyalakshana	Director General Department of Agriculture	Thailand
Dr. Tojib Hadiwidjaja	Minister of Agriculture	Indonesia
Dr. Go Ban Hong	Director, Central Research (Bogor) Institute for Agriculture	Indonesia
Dr. I. M. bin Jamil	Director Department of Agriculture	Malaysia
Dr. B. P. Pal	Director General Indian Council of Agricultural Research	India
Mr. M. F. Dad Khan	Director, Department of Agriculture Northwest Frontier	Pakistan
Dr. D. L. Umali	Vice President University of the Philippines	The Philippines
Dr. F. T. Orillo	Dean, College of Agriculture University of the Philippines	The Philippines
Dr. W. Hugh Walker	Director Arid Lands Agricultural Development Program	Ford Foundation Lebanon
Dr. Robert Havener	Representative Ford Foundation	Ford Foundation Pakistan
Dr. Peter Oram	Assistant Director of Policy Advisory Bureau	FAO, Rome
Dr. Nathan M. Koffsky	Consultant Economic Policy	Ford Foundation New York
Dr. Clarence C. Gray, III	Associate Director	Rockefeller Foundation New York

Name	Title	Country/Program
Dr. Guy B. Baird	Director, Indian Agricultural Program	Rockefeller Foundation India
Dr. Delane E. Welsch	Visiting Professor Economics Kasetsart University	Rockefeller Foundation Thailand
Dr. Robert F. Chandler, Jr.	Director, IRRI The Philippines	Rockefeller Foundation The Philippines
Dr. A. Colin McClung	Associate Director IRRI	Rockefeller Foundation The Philippines
Dr. D. S. Athwal	Assistant Director for Administration	IRRI The Philippines
Dr. Richard Bradfield	Agronomist, IRRI	Rockefeller Foundation The Philippines
Dr. Randolph Barker	Agricultural Economist IRRI	Rockefeller Foundation The Philippines

3. Others consulted include:

Name	Title	Country/Program
Dr. Leland R. House	Geneticist	Rockefeller Foundation New Delhi, India
Dr. Kenneth O. Rachie	Visiting Professor Plant Breeding	Rockefeller Foundation assignment to Makerere University, Kampala, Uganda
Dr. Bobby L. Renfro	Plant Pathologist	Rockefeller Foundation New Delhi, India
Dr. A. M. Weisblat	Economist	Agricultural Development Council, New Delhi, India
Dr. James E. Johnston	Animal Scientist	Rockefeller Foundation Bangkok, Thailand

APPENDIX 3

Present population and cultivated[1] land on each continent, compared with potentially arable land

Continent	Population in 1965 (millions of persons) (1)	Area in billions of acres			Acres of cultivated[1] land per person (5)	Ratio of cultivated[1] to potentially arable land (percent) (6)
		Total (2)	Potentially arable (3)	Cultivated[1] (4)		
Africa	310	7.46	1.81	0.39	1.3	22
Asia	1,855	6.76	1.55	1.28	.7	83
Australia and New Zealand	14	2.03	.38	.04	2.9	2
Europe	445	1.18	.43	.38	.9	88
North America	255	5.21	1.15	.59	2.3	51
South America	197	4.33	1.68	.19	1.0	11
U.S.S.R.	234	5.52	.88	.56	2.4	64
Total	3,310	32.49	7.88	3.43	1.0	44

[1]Our cultivated area is called by FAO "Arable land and land under permanent crops." It includes land under crops, temporary fallow, temporary meadows, for mowing or pasture, market and kitchen gardens, fruit trees, vines, shrubs, and rubber plantations. Within this definition there are said to be wide variations among reporting countries. The land actually harvested during any particular year is about one-half to two-thirds of the total cultivated land.

Source: THE WORLD FOOD PROBLEM - VOL. II, page 434.

APPENDIX 4

AN INTERNATIONAL INSTITUTE FOR RESEARCH ON RICE AND UPLAND CROPS

Richard Bradfield, IRRI

Rice is, and will probably continue to be, the most important single food crop in the monsoon belt of Asia, but it alone cannot provide the balanced diet needed by its people. The increase in yields of rice resulting from recent research, largely at I.R.R.I. and cooperating institutions, will make it possible to produce all the rice needed and at the same time free land for the production of other crops, especially during the dry season. The research needed on both rice and upland crops which will often be grown on the same farms, should be directed toward the development of integrated, efficient and balanced systems of farming.

If research on rice is done at I.R.R.I. and that on the other crops at another institute in a different location in a different country, one or the other of the following is likely to result:

1. Independent systems for rice and upland crops will be developed instead of integrated systems which will likely be more flexible and sounder, agronomically and economically.
2. Unnecessary and undesirable duplication of efforts will result at both institutions.

Farmers and agricultural leaders of the area to be served by the existing and the proposed new Institute will be better served if the Institutes are developed together rather than independently. They are already looking to

I.R.R.I. for international leadership in rice research. Why should they have to go elsewhere for help with problems of growing other crops with rice? There are now, and will continue to be, areas in the region which are not well suited to rice and in which the major interest will be upland crops, but such areas are now, and will probably continue to be, a relatively small proportion of the total. Such areas can be found within a few miles of I.R.R.I.

The new work which is needed on upland crops can be done quicker and more economically at an established and world renowned institute like I.R.R.I. than at a new institution in a different country. As evidence, consider the length of time it has taken to get the new Institutes in Nigeria and Colombia into full operation.

The arguments for locating I.R.R.I. in the Philippines are equally cogent for the proposed Institute. Communications are much easier in a country in which the English language is widely used. The new Institute should be located near a strong University, with a good college of agriculture and graduate school. The College of Agriculture of the University of the Philippines is certainly one of the best, if not the best, in the region. Students from many countries in the region are already coming here for graduate work. The faculty, predominantly young, is well-trained. The campus renewal program, which will provide excellent physical facilities for the college, is already about 90% completed. Good cooperative relations between the College and I.R.R.I. have already been established and could almost automatically be extended to the new development.

Both the Rockefeller and Ford Foundations have been substantially committed to the development of strong, integrated Centers of research and education instead of numerous smaller and weaker institutions. The proposal to locate the new research at I.R.R.I., with its close relationship to the University of the Philippines, would be in line with this established policy.

Many of the existing facilities at I.R.R.I. could, with but modest changes and additions, be shared with the new group. Many of the administrative and service units, the library, statistical services, etc., would not need to be built from the ground up but could be expanded at a more modest cost to meet the enlarged demands.

Most of the I.R.R.I. professional staff have found Los Baños a delightful place in which to live. A few more families could be added to the present community very easily. The Cornell University Contract with the College is already phasing out. The Foundation built several very nice houses for this group. It <u>might</u> be possible to make a mutually advantageous arrangement for the use of some of these houses for the new staff.

More land for research would be needed. Additional flat land suitable for rice and associated upland crops can probably be obtained adjacent to the present farm. Additional water for irrigating it can probably be obtained by sinking a few more tube wells. As mentioned above, an area of rolling upland soils suitable for experimental use can be found within a few miles of Los Baños.

I now come to the reservations which Clarence Gray indicates that some have regarding the influence that this merger would have upon I.R.R.I. Will it "dilute and compromise the work on rice?" This question is important. No one, I am sure, wants to take any step which would impair the work of I.R.R.I. on rice in any way. In my opinion, it would probably have just the opposite effect. This will be influenced by the course which I.R.R.I. decides to take in the next decade.

Let us speculate a little on this vital point. It was the subject of an international conference held at I.R.R.I. almost exactly a year ago, (September 30 to October 3, 1969).

A report on this conference, "Rice Research and Training in the '70's," was published this year and is widely available. Concluding observations are summarized on pages 26-28. I have read and reread this section but fail to find any points which would be "compromised or diluted" by the addition of 8 to 12 scientists working primarily on crops other than rice but concerned at times with problems of growing these crops in rotations with rice.

Rice in monsoon Asia is grown under 3 different levels of water management:

(1) Complete water control at all times (fully irrigated) - This system is used on from 25-35% of the rice area of the region. Because of high yields, it produces a higher proportion of the total rice crop. The work of I.R.R.I. to date has been concentrated primarily on increasing rice yields under this system of management. This was, in my opinion, a wise decision, because crop research usually pays highest dividends when the environment, especially the water supply, is under control.

(2) Rainfed paddy is grown by transplanting rice seedlings into puddled soil just as in (1) with the difference that the farmer is entirely dependent on the whims of natural rainfall for water to puddle his soil and to meet the water needs of the crop until it is harvested. Under these conditions yields are lower and much more variable from year to year. Famines

in Asia are frequently due to a failure of the monsoon rains to provide enough water for the huge rainfed area which is said to make up from 65% to 75% of the total rice area, and almost as large a proportion of the rice farmers. While these farmers have benefited by much of the research on irrigated rice at I.R.R.I., little effort has been directed by its rice specialists to the water deficit problems characteristic of this system. This problem is worthy of more attention at I.R.R.I.

(3) Upland rice is usually grown on rolling land, with little or no effort made to collect or control the water from rainfall. Yields are usually very low and the possibilities for improving them very limited because of the difficulties and cost of improving the water supply. Many students of the problem feel that the land now planted to upland rice should be planted to other crops such as corn or sorghum.

Some work on crops other than rice has been in progress at I.R.R.I. for over six years. Most of this work has also been done under irrigation, but several experiments have been conducted over the last 4 years under rainfed conditions. This work, commonly referred to as the Multiple Cropping Project, illustrates, in a small way, some of the problems, possibilities, and advantages of doing research on upland crops at I.R.R.I. Good yields of a wide range of food crops, sweet potatoes, sweet corn, corn, sorghum, soybeans, mungbeans and a wide range of vegetables have been regularly produced in rotations which gave rice yields of 4.5 to 6.0 tons per hectare. To do this has required, however, some modifications in the conventional methods of growing rice.

Evidence of the need to modify the traditional system of paddy rice culture is, I think, most convincing in the case of our experiments with rainfed paddy. The food production potential of this huge area will not be attained until the present system is drastically modified. It is high time that more research be done in this area. I am convinced that if a well-directed and well-supported program is initiated in this field, techniques for doubling food production can be developed in less than ten years. In addition, the quality of the food supply can be improved by crop diversification and protein and Vitamin A deficiencies can be eliminated even for very low income people. To do this will require the close collaboration of rice and upland crop specialists. This close collaboration can be best attained and insured by having them rubbing elbows and exchanging ideas daily in the same Institute.

APPENDIX 5

1. Selected Countries with Tropical Rainy (VI) and Seasonally Humid (V2) Climates:

Asia

India	Philippines
Pakistan (East)	Indonesia
Burma	Malaysia
Thailand	Ceylon
Cambodia	Yemen
Vietnam	

Afria

Sierra Leone	Congo
Guinea	Angola
Ghana	Ethiopia
Nigeria	Malagasy Republic
Cameroon	Uganda
Central African Republic	Kenya
	Tanzania

South America and Central America

Mexico	Brazil
Guatemala	Peru
Venezuela	Cuba
Colombia	Ecuador
Guiana	Honduras
Costa Rica	Nicaragua
Panama	

Australia

2. Selected Countries with Wet-Dry (V3) and Tropical Dry Climates (V4):

<u>Asia</u>

India
Pakistan (West)
Burma
Thailand
Yemen

<u>Africa</u>

Mauritania
Senegal
Mali
Upper Volta
Niger
Chad
Malagasy Republic
Mozambique
Sudan
Ethiopia
Nigeria
Southwest Africa
Angola
Somalia
Kenya
Rhodesia

<u>South America and Central America</u>

Mexico
Peru
Brazil
Argentina

<u>Australia</u>

APPENDIX 6

An Impressionistic View of the Need or Adequacy of Present Technical Knowledge for Accelerating Farm Production of Food Crops and Livestock, and for Improving Farm Productions Systems*

1. CROP-ORIENTED TECHNOLOGY - CEREALS

Crop	Monsoon Asia	South Asia	Near East N. Africa	Sudanian Africa	Tropical Africa	Tropical Latin America	Temperate Latin America	Andean & Mountain Areas	Comments
Rice									
Irrigated Controlled	0	0	0	+	-	0	0	-	
Deepwater	++	++	-	-	?	-	-	-	
Swamp	-	-	-	-	++	?	-	-	
Upland	+	+	-	++	+	+++	-	-	
Wheat									
Irrigated	-	0	+	+++	-	-	?	-	0 in East Africa
Rainfed Spring	-	+++	+++	-	0	-	+++	-	
Rainfed Water	-	-	+++	-	-	-	-	+++	
Barley									
Rainfed Spring	-	+++	+++	-	-	-	?	-	
Rainfed Winter	-	-	++	-	-	-	-	?	
Millet									
Pennisetum	-	+++	-	+++	++	?	-	-	
Eleusine	-	++	-	-	++	?	-	-	
Sorghum									
Rainfed Humid	+++	+++	+++	+++	++	?	+	?	
Rainfed Semi-arid	-	+++	+++	+++	++	?	-	?	
Maize									
Irrigated	-	0	++	++	-	?	-	-	
Rainfed Humid	+++	++	++	++	+++	++	++	++	
Rainfed Semi-arid	-	+	-	-	+++	-	-	-	

2. CROP-ORIENTED TECHNOLOGY - OTHER CROPS

Crop	Monsoon Asia	South Asia	Near East N. Africa	Sudanian Africa	Tropical Africa	Tropical Latin America	Temperate Latin America	Andean & Mountain Areas	Comments
Leguminous Oilseeds			(1)						(1) Groundnuts irrigated in Near East
Groundnuts	+++	+++	+	0	+++	+++	++	-	
Soya	+++	++		+++	+++	+++	?	+++	
Grain Legumes									(1) Maybe unimportant because of adequate animal protein
Temperate	-	+++	+++	+++	-	-	?(1)	++	
Tropical	+++	+++		+++	+++	+++	+	+	
Tropical Root Tubers	++	+	-	-	+++	+++	-	-	
Plantains	++	+	-	-	+++	+++	-	-	
Irish Potatoes	-	++	0	-	-	-	?	+++	
Fruits and Vegetables									See Annex

3. LIVESTOCK-ORIENTED TECHNOLOGY

Crop	Monsoon Asia	South Asia	Near East N. Africa	Sudanian Africa	Tropical Africa	Tropical Latin America	Temperate Latin America	Andean & Mountain Areas	Comments
Tropical Bovines									
Breeding research using present fodders	+	++	++	+++	+++	++	0	?	
Fodder research using present breeds	+++	+++	+++	+++	+++	+++	+++	?	
Intensive animal management altering both fodders and breeds	+++	+++	+++(1)	+++	+++	+++	+++	?	(1) Mainly under irrigation
Pastoral animal management systems	-	+++	+++	+++	-	-	++	?	
Livestock processing and marketing	+++	+++	++	+++	+++	+++	+	?	
Pigs and poultry									See Annex

4. FARM PRODUCTION SYSTEMS TECHNOLOGY

Crop	Monsoon Asia	South Asia	Near East N. Africa	Sudanian Africa	Tropical Africa	Tropical Latin America	Temperate Latin America	Andean & Mountain Areas	Comments
Difficult Environments									
1. Low Rainfall Areas	+	+++	(+++(1)	+++	-	-	-	-	1. and 2. can be tackled together in several countries of Near East and North Africa
2. High Mountain Areas	-	+	(+++	-	++	-	-	+++	
3. Shifting Cultivation Areas	+++	+++	-	-	+++	+++	-	-	
Water Resources and Use									
Inventory of Water Resources	++	+++	++	+	+	?	?	-	
Methods of Water Exploitation	+	++	+++	+++	+	?	?	-	
Methods of On-Farm Water Management	+++	+++	+++	+++	++	+	?	-	

5. TECHNOLOGIES TO PREVENT LOSSES

Crop	Monsoon Asia	South Asia	Near East N. Africa	Sudanian Africa	Tropical Africa	Tropical Latin America	Temperate Latin America	Andean & Mountain Areas	Comments
Grain Storage, Drying, Milling & Processing	+++	+++	+	+++	+++	+++	0	++	
Rodent Control (1)	+++	+++	?	?	?	?	?	?	Could this be on a project basis?

Legend:	0	Present technical knowledge is generally adequate to support production extension programs where the idiosyncrasies of the farming environment do not demand specially designed or particularly adapted research results.
	+	There seems to be a general deficiency in present technical knowledge of how to raise farm output. The number of + marks gives a rough indication of the relative extent of the deficiency, +++ indicating the greatest need for more research, and ++ and + indicating respectively lower levels of need.
	?	Situation unknown to the authors of the table.
	-	The subject matter is not relevant to the farming of the geographic region.

* This table must be used with great caution. It was not discussed fully at the Conference and little attempt was made to probe its contentions or verify its pretensions. It was presented to the Conference as a rough "cocktail session" outline of problem areas as seen by Oram, Fournier and Hopper. It reflects only their impressions gathered from their own experience. The authors and many members of the Conference suggested the need for greater subject matter and geographic detail. Greater detail was not included, however, because more "boxes" would have led to more question marks and, perhaps, to even greater errors of judgment. The table was appended to the Conference summary because, for all its limitation, it was found useful as a first approximation exposure of needed agricultural research.

In developing the table, the authors discussed and then specifically excluded consideration of plantation food crops. The exclusion is not a reflection of the unimportance of these crops as food sources in many areas of the world. The decision to exclude them from the table was taken purely on pragmatic grounds of the inadequacy of the authors' own knowledge about them and the need to keep the table within reasonable bounds.

It should be pointed out that the table does not indicate the relative importance of each subject matter item in the agriculture or in the agricultural development opportunities of a given geographic region. It is only a rough ranking of the adequacy of the technical knowledge available upon which to found the acceleration of agricultural modernization.

Taken from: A Summary of Findings and Suggestions of Agriculturists from Development Assistance Agencies, Villa Serbelloni, Bellagio, Italy, February 3-6, 1970 (Conference sponsored by The Rockefeller Foundation).

APPENDIX 7

A STATEMENT ON THE NEED FOR A CONCENTRATED AND SUSTAINED RESEARCH EFFORT ON SORGHUM AND THE MILLETS TO SERVE AFRICA AND ASIA*

A. INTRODUCTION

This paper originally arose from discussions among Haldore Hanson, Brian Beck, Hugh Doggett, and Leland House while at the seminar on "Research on Sorghum and Millet in West Africa," held at Bambey, Senegal, in September, 1970. It has been modified and expanded subsequently by Leland House and Guy Baird to be more complete as a position paper for an international center for research on sorghum and millets.

Sorghum and millets are the major group of dry land cereals grown in Africa (entire continent) and western Asia (India to the Mediterranean). Together they occupy over 71,000,000 hectares (ha) in this area, compared with 21,000,000 ha cultivated with maize. We estimate conservatively that some 400,000,000 people eat sorghum or millet as their staple food, after making allowance for that part of the sorghum and millet crops used for forage. In Africa alone, 55 percent of the total area sown to cereals is occupied by sorghum and the millets; and in Africa and western Asia combined, 42.5 percent of the total cereal acreage is in sorghum and millets.

Sorghum and the millets are cultivated in the drier portions of India and West Pakistan, with special concentration in the Deccan plateau of India; and are grown throughout most of eastern and southern Africa, and all of the savannah zone of western Africa. Sorghum and

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* Drafted by Dr. Leland House, Geneticist, The Rockefeller Foundation, New Delhi, India.

the millets form the staple food of the poorer peoples of these areas who have no other subsistence crop, and whose population is expanding.

B. EXISTING RESEARCH PROGRAMS

A brief survey of existing research programs for these crops is as follows:

North, Central and South America: The research effort for sorghum and millets in the Western Hemisphere is reasonably satisfactory for the forage and feedgrain purposes of those continents. The grain is used almost exclusively for animal feed.

OAU/STRC Project 26 in Africa: The Organization of African Unity, with headquarters in Addis Ababa, through its Scientific and Technical Research Committee (STRC), with headquarters in Lagos, Nigeria, has organized a Major Cereals Research Project, generally referred to as Project 26, which specializes in maize, sorghum and millets. This Project has done very creditable work since the mid-1960's, working from headquarters in Samaru, Nigeria, for two English-speaking countries in West Africa; from research stations in six French-speaking countries of West Africa; and in two countries of the East African Community with special focus at Serere, Uganda. Project 26, largely financed by the United States Government, may phase out by 1975, and the team of sorghum and millet researchers would be terminated gradually.

French Government research in French-speaking Africa: The French Government, especially the French research organization, IRAT, maintains research facilities in most French-speaking countries of tropical Africa, and has done outstanding work in sorghum and the millets with notable work at Bambey, Senegal. Some of this work is in cooperation with Project 26 (above) and some is separate. French aid funds are being reduced, and in 1970, this reduction has especially affected the agricultural research organizations, including IRAT. IRAT is asking African Governments to bear a larger part of the cost of French research, to which most of the African Governments, especially those in the drier savannah zone, have not been able to contribute. The French scientists at the Bambey Conference have predicted a substantial reduction of French contribution to sorghum-millet research during the 1970's.

India: The Indian Government and The Rockefeller Foundation have cooperated for more than ten years on cereal research, including the present all-India cereals improvement programs. Two of the latter are the all-India Sorghum and all-India Millets Improvement Projects. The Foundation has been able to provide a limited number of technical staff, travel grants and a dollar budget for needed equipment and supplies not available in India. The number of technical staff has gradually been reduced; staff members leaving during the last several years have not been, and will likely not be, replaced.

The Rockefeller Foundation has attempted to initiate an international program for sorghum and millets based in India as an extension of the all-India programs. It appears that this is not likely to materialize. More recently consideration was given to inclusion of sorghum and millets improvement as part of an upland crops research institute in Asia.

Conclusion on present research programs: Under current arrangements there is no certainty that any international agency will continue to engage in sorghum and millet research, on a continent-wide or world-wide basis, beyond 1975. Only in-country programs are certain to be operative, with their inherent drawbacks of limited financing, limited staffing, specialized ecology, and the lack of a world network of scientific exchanges.

We believe that an international center for sorghum and millet research is necessary to produce the dramatic increases in yield which will be required to keep up with the African and Asian population growth.

In separate sections below we review the possible alternative locations for such an international effort, and the functions of an international institute.

C. POSSIBLE CHOICES OF LOCATION FOR AN INTERNATIONAL SORGHUM-MILLET PROGRAM

The institute must be situated where the ecology and agro-climatological conditions are representative of the major sorghum and millet growing areas of Asia and Africa. Most major pests and diseases of the crops should be endemic to the location.

To attract an international staff to an institute, it is essential that there be facilities both for families and for the intellectual life of the scientific group. These conditions require:

a) Easy access to a cosmopolitan urban center with adequate schools, medical facilities, and consumer goods.

b) Easy access to an international airport with frequent connections both to the principal sorghum-millet growing areas and to the main scientific centers of the world.

c) Proximity of a university community of international caliber, and preferably a community of other scientific organizations, to provide intellectual stimulus, supplementary scientific facilities, and training opportunities.

A review of the present four international agricultural research institutes assisted by the Rockefeller and Ford Foundations (CIMMYT, CIAT, IRRI, and IITA) will indicate that all these supporting conditions have been met, for their individual research purposes.

However, none of the present international research institutes named above offers all the necessary research conditions for sorghum and millets.

CIMMYT in Mexico has sorghum in its charter, and it is recommended that a sorghum-millet project be located in Mexico if other alternatives are not possible. A particular limitation of CIMMYT is that the shootfly, a major pest of the crop in Africa and Asia, is not present in North and South America, and the stem borer complex in the Western Hemisphere is not the same as that of Africa and Asia. Millets are unimportant in the Western Hemisphere (423,000 ha reported by Argentina and Haiti in the FAO Production Year Book, 1967).

CIAT in Colombia has the same basic limitations as CIMMYT in Mexico.

IRRI is equally unsuitable. In the Philippines, sorghum is a very minor crop, and the millets are not grown. The shootfly is rarely found. The pest and disease situation in the Philippines is atypical of the sorghum-millet areas of Asia and Africa.

IITA in West Africa is focusing its research on the humid tropics, which do not produce sorghum and millets, and IITA has stated that its primary crop research programs will not include sorghum and millets. In addition, the Ibadan area is atypical of the drier sorghum-millet areas in Africa and Asia. If IITA were assigned work on these two crops, it would be necessary to conduct a large portion of the research at another site.

Having decided to look elsewhere for a more suitable site, we have examined other alternatives below.

1. Asia

India: India has roughly 38 m. ha of sorghum and millets combined, and cultivates about 40 percent of the world acreage of these crops (excluding mainland China, for which current acreage is not available). It is in India that the food problems of the future are likely to be largest. A Green Revolution has already begun in India, and the National Programs on sorghum and millets are already under way. Within India, work on sorghum has centered at the Hyderabad area; that on millets at Delhi (IARI). At Hyderabad three crops a year are possible. India has expressed interest in developing a strong national center for sorghum improvement with provision for international activities.

Sorghum and millets are cultivated over the entire country but the areas are very small in the eastern states. Only one major cropping season (July sowing) is possible in North India as winter temperatures are too low and summer (March sowing) temperatures too high for effective plant growth. The sorghum belt of India incorporates the states of Maharashtra, Andhra Pradesh and Mysore. It is in this area that three crops a year can be grown and a site for an international institute could be sought. There are three cities, well connected by air, and situated close to agricultural universities where an international project could be centered: Hyderabad, Poona and Bangalore. The Deccan Plateau is not blessed with good ground water supplies so it would be necessary to carefully search these areas to find a suitable location with assured water.

The climate is suitable for sorghum and millets cultivation; adequately representing most producing areas of the world. It would not be possible to represent the higher elevation (above 5000 ft.) areas found particularly in East and South Africa.

Living conditions in these three cities pose certain problems. Schools for children are a particular source of concern. The American School is in Delhi so it would likely be necessary to send children away from the home. Schools in Hyderabad have not been suitable and have deteriorated following recent extended periods of civil unrest.

India is a large country and politically involved in world affairs. Its relationship with Pakistan and Israel, two countries concerned with this project, is poor, resulting in difficult exchanges of individuals and seeds. Internally, we are aware of complicated procedures resulting in delays in the movement of people and items such as seed. Changes in these problems are very slow in coming but progress is being made. Some difficulties could be expected in negotiating such a project in India.

Pakistan: Pakistan is not suitable. Only one major crop a year can be grown in the sorghum areas of West Pakistan during the wet season; during the winter season, temperatures are too low for the growth of sorghum and millets. One sorghum crop can be taken during the summer season, but is restricted in scope because of very high temperatures. East Pakistan is ecologically unsuited to sorghum and the millets.

Thailand: Thailand is a possible site for a program on sorghum, but it is on the eastern edge of the sorghum-growing areas of the world. The sorghum midge, a major pest of the crop, is not present. Millets are not grown. Thailand is currently self-sufficient in food crops and is only interested in the development of sorghum as an export crop.

2. Africa

West Africa: In West Africa, no suitable site seems to be available. Samaru, Nigeria, which now serves as the principal center of research in English-speaking West Africa, lies in a specialized ecological area which can produce only one crop a year because of low night temperatures in the dry season. Bambey, Senegal, which serves as the principal sorghum-millet research center in the French-speaking countries of western Africa has inadequate irrigation facilities. However, even with irrigation, Bambey suffers from low night temperatures during the dry season, which would thus permit only one crop a year.

Ethiopia: Ethiopia is one obvious site for an institute in East Africa. Ethiopia grows almost 5,000,000 ha of sorghum and millets and contains the centers of variation of sorghum, pearl and finger millets. The pressure on these crops is probably high enough that such an institute would be welcomed in Ethiopia. The most likely center would be near Addis Ababa, where all facilities and communications are good. It appears that there are locations in the Rift Valley near Addis with irrigation facilities for three crops a year.

Ethiopia appears to be relatively neutral internationally so that contact with virtually all African, Near East (Israel included) and Asian (India and Pakistan) countries would be unencumbered. Entry into the country is uncomplicated - other operational procedures require further evaluation.

Kenya: Nairobi is another site to be considered in East Africa. It should be possible to find a site around Nairobi at a low enough altitude to grow three crops a year with irrigation. It has excellent urban family facilities and communications, and is within easy reach of West Africa, Asia and Addis Ababa (i.e., close to the centers of variation). If it is necessary to reduce costs, an institute for sorghum and millets in East Africa might appropriately be associated with one for animal science which also is under consideration for this area.

Kenya is concerned with international problems, particularly with Uganda and Tanzania in the East African community. It is expected that the community would be stable but freedom of movement, while not restricted, could become somewhat complicated. Evaluation of operational problems would be required. Sorghum seed has moved easily in and out of Uganda, but there are restrictions on the movement of maize seeds.

The growing conditions in both Ethiopia and Kenya would adequately resemble those of the Deccan Plateau in India.

Conclusions on location

To sum up this review of alternative locations, India offers the advantage of a major producer of sorghum and millets, grown under ecological conditions typical of the cropping areas for sorghum and millets in both Asia and Africa, and with the major problems, notably insect pests. The doubts are primarily associated with possible governmental attitudes.

In East Africa, a suitable site could most likely be found within easy driving distance of the capitals of Ethiopia and Kenya, but at elevations about 2000-3000 feet lower than the two capital cities. Both cities are situated near the edge of plateaus, and the Rift Valley gives access to the required lower elevation and ecological conditions for sorghum and the millets.

D. THE FUNCTIONS OF AN INSTITUTE FOR SORGHUM AND MILLETS

The functions of such an institute can be divided into several broad, more-or-less overlapping categories. The availability of large germplasm collections of sorghum and several of the millets is important to each category. There are a large number of millets used as food crops; priority would be given first to pearl millet (*Pennisetum typhoides*), second to finger millet (*Eleucine coracana*), and third to foxtail or Italian millet (*Setaria italica*). Research on foxtail and other millets of lesser importance would be delayed until substantial accomplishments had been made in the first two. It is necessary that appropriate teams of scientists be brought together to maximize the opportunity to generate useful results in a minimum period of time.

Impact research: This type of research is characterized by the opportunity to make a rapid increase in production potential, using known procedures, in a fairly short period of time. It involves such things as the identification of high-yielding varieties and hybrids and their combination with a package of management practices, and the development of cropping sequences where increased yield per unit area per unit time is the objective.

Production research: This type of research leads to an increase in use of the crops over large areas. The research involves such problems as enhancing insect and disease resistance, drought tolerance, bird resistance, tolerance to witch weed, etc. It would involve research related to the improvement in management practices, for example, time of sowing to avoid an insect or disease problem, identification of a new insecticide which is more effective or can be more economically applied, the identification of a herbicide which more effectively controls witch weed, a crop management procedure that results in more effective use of available moisture. Such research results in a lowering of production costs. It would also involve development of desirable grain characteristics to improve market acceptability or to improve weatherability of the seeds, i.e., factors which enhance its market value.

Exploratory research: This type of research is more fundamental in scope, not necessarily having an immediate application, but resulting in the continuing increase in yield potential. Such research would address itself to questions such as:

1. Problems related to the use of composites as a breeding approach.
2. The development of techniques for mass rearing of insects, or of an inoculation technique.
3. Plant manipulation to maximize floret number.
4. The identification of antibiosis and its incorporation into agronomically valuable types.
5. Learning more about the nature of drought tolerance and the useful application of mechanisms of such tolerance.

Service functions: The service functions of the institute would be several:

a) To undertake a training program to strengthen the knowledge and skills of the individuals from various country programs.

b) To expand, maintain, classify, and distribute the world collection of sorghum and millets.

c) To have a documentation service and be a source of information and literature both to the institute and those working elsewhere.

d) To provide seeds of lines or populations superior for some trait(s); and particularly to service international nurseries and yield trials such as the ones for yield, shootfly, and downy mildew currently in operation.

e) To have an installation for the mass rearing of insects, particularly for shootfly; eventually it may be possible for midge. This service could be available to screen lines sent from any location. Stemborers vary considerably with location, however a similar service could be provided to those areas where the stemborer was the same as at the institute. Possibly the institute could provide several screening services; particularly where effective or uniform screening is otherwise difficult to attain, for example, for tolerance to witch weed or tolerance to downy mildew.

f) To sponsor periodic meetings and occasional seminars to further promote research particularly at the institute.

APPENDIX 8

Sorghum and Millets

1. Leading Sorghum & Millets Producing Countries*

North and South America	Sorghum	Millets
	1000 Hectares	
U.S.A.	5,663	-
Argentina	1,266	210
Mexico	680	-
Haiti	-	230
El Salvador	130	-
Asia		
India	18,731	19,036
Pakistan	474	736
Burma	-	140
Yemen	420**	-
Nepal	-	100**
Africa		
Nigeria	5,000	5,200
Ethiopia	3,600**	-
Niger	500	1,800
Sudan	1,168	637
Upper Volta	1,209	766
Tanzania	1,300**	-
Senegal	1,036**	-
Mali	910**	-
Cameroon	500**	-
USSR		
Australia		

* 1968 figures taken from: FAO Production Yearbook, Vol. 23, 1969.
** Unspecified sorghum and millets.

2. Comparison of Sorghum and Millets Statistics*

REGION	ACREAGE in 1000 Ha.		PRODUCTION in 1000 Metric tns.		YIELDS Metric tns./Ha.	
	Sorghum	Millets	Sorghum	Millets	Sorghum	Millets
EUROPE	125	36	389	51	3.11	1.42
NORTH AND CENTRAL AMERICA	6,637	230	20,767	150	3.13	0.65
SOUTH AMERICA	1,319	210	2,095	229	1.59	1.09
ASIA	19,420	20,600	10,350	8,162	0.53	0.40
AFRICA	9,728	9,773	7,528	5,142	0.77	0.53
WORLD	37,487	33,924	41,598	16,421	1.11	0.48

* Source: FAO Production Yearbook, Vol. 23, 1969.

3. Selected Sorghum Programs

South and Central America

Argentina

Criadero "Continental"
Murphy, Santa Fe

Híbridos KeKalb
Buenos Aires

Estación Exp. Agropecuaria
Córdoba

Brazil

Inst. de Pesquisas Agronômicas
Recife

Escola de Agronomia
Fortaleza

Chile

Inst. de Investigaciones Agropecuarias
Santiago

Colombia

CIAT
Cali

Mexico

CIMMYT
Calle Londres

Africa

Cameroon

Station Agricole

Nigeria

Ahmadu Bello University
Zaria

Senegal

Bambey Agric. Exp. Station
Bambey

South Africa

Commercial Seed Companies
Natal and Pretoria

Uganda

East African Common Serv. Org.
Serere

Makerere University
Kampala

Ethiopia

Asia

India

All-India Coordinated Sorghum Project (ICAR & IARI)
Hyderabad

Pakistan

Corn and Sorghum Projects
Yousafwala

Taiwan

Taichung Dist. Agric. Imp.
Taichung

Thailand

Kasetsart University
Bangkok

Australia

C.S.I.R.O.
Canberra

Dept. of Primary Industries
Via Warwick

Kimberly Research Station
Kununurra

4. Comments on the potential usefulness of sorghum and millets[1]

The potential for sorghum and millets is less well established than other cereal crops, although sorghum and millets are cultivated extensively throughout the world. Together they occupy more than 100 million hectares of land in the world. It is quite possible that these cereals may find a greater niche in the agriculture of warm temperate to tropical regions by virtue of the following:

a. Sorghum and millets probably are more efficient in water use and nutrients than maize, for example, in respect to grain production as a result of more extensive root systems, greater tolerance of stress, and higher grain-straw ratios.

b. Many strains of sorghum and millets are relatively short in duration and tolerate less favorable conditions. Because of these characteristics which enable them to fit well into cropping systems and rotations, they can be used to intensify the use of crop lands.

c. Sorghum and millets are generally more tolerant of drought, heat and alkalinity than maize. Moreover, sorghum frequently performs well on heavy soils under water-logged conditions, while pennisetums (pearl millets) grow better in sandy soils.

d. Grain quality of sorghum and millets is often superior to that of maize (except possibly high lysine strains). Sorghum averages about twenty percent more protein (11-12%) and pennisetums usually range from 50-80 percent higher in protein than maize. Both crops tend to have a better balance of essential amino acids, including 2-3% lysine. The pennisetums are also high in fats (5-7%) and are high in phosphorus, including phytin.

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[1] Taken principally from the report by K. O. Rachie, The Rockefeller Foundation, Some Impressions on Sorghums, Millets and Other Crops for the Middle East, May 8, 1970.

Rachie is of the opinion that the sorghum and millets can compete well with maize in potential usefulness. All three crops have excellent forage and possess similar grain qualities. For example, both sorghum and pennisetums have yellow endosperm (carotene), sugary endosperm, flinty endosperm and waxy starch (not confirmed in pennisetum). In addition some strains of sorghum and another species of millet (Eleusine Corcana) have good malting qualities.

An important role for sorghum and millets would be to increase productivity through new uses. This might involve double-cropping after wheat or other crops, growing on residual moisture or where climate (high temperatures) and difficult soil conditions (water-logging, alkalinity, salinity, or coarse-textured soils) preclude growing other crops in certain seasons or areas.

APPENDIX 9

An international institute, adequately financed, equipped and staffed, modeled on the lines of successful international centers in The Philippines and Mexico, carrying out an accelerated, coordinated program drawing on the best of worldwide resources - materials, techniques and talents - would have the best chance of producing the kind of support nations need to make desired increases in food and incomes for farm people in monsoon and low-rainfall Asian areas (V3 and V4 climates). Outlined below are suggestions for such an institute.

AN INTERNATIONAL UPLAND CROPS INSTITUTE

Objectives

With regard to low-rainfall and seasonally wet-dry regions, assist nations in Asia to:

1. Increase agricultural productivity and real incomes of farmers, and

2. Develop cropping patterns and systems of farming which optimize the use of natural and human resources for a permanently and increasingly prosperous agriculture and society.

The Institute would achieve its objectives in several ways. Through the solution of soil, water and crop problems constraining productivity, the Institute would generate useful technology while demonstrating methods and techniques which individuals and nations could use in the solution of their problems. Thus, the Institute should strive toward universal applicability of results throughout the region regardless of local agricultural patterns and problems.

The Institute would develop, maintain, and make available services and research materials not generally available in individual countries, and which generally would be beyond country capabilities. In this regard the Institute would assemble a staff of resident scientists and consultants with unique and exceptional competencies to assist in the solution of regional problems. The Institute would stimulate and develop regional cooperation and provide facilities and services, including training, from which national programs could secure the best in the way of information, materials and services. In short, the Institute would provide needed support not otherwise readily available to national programs.

Activities

The Institute would undertake research and training activities which emphasize the development of materials, methods and techniques useful for the solution of diverse problems of agricultural productivity and systems of farming in limited and uncertain rainfall regions of Asia, with special regard to sorghum, millets, chick-peas and pigeon peas. While the location of the Institute would govern to a degree the specific research activities, priority would be those of wide applicability so that research results would be readily useful to many national programs.

Sorghum, millets, chick-peas and pigeon peas have wide adaptation in the drier, rainfed regions of Asia, and could be expected to fit into cropping systems in the region. With such crops, the Institute could carry out programs which would:

1. Collect, describe, catalogue, maintain and distribute the entire range of world germplasm.

2. Arrange for cooperative screening of germplasm for adaptation and resistance to diseases and insect pests.

3. Conduct research on physiological reactions to environmental stress of the various germplasm sources with the view of developing better varieties and management practices for increased productivity under Asian conditions.

4. Conduct interdisciplinary research (breeding, physiology, agronomy, plant protection, agricultural engineering, farm management, etc.) to develop economic cropping patterns and land-use systems with special concern for the use of labor-intensive technology.

5. Conduct interdisciplinary research (breeding, physiology, agronomy, plant protection, agricultural engineering, agricultural economics, etc.) to develop drying, storage, processing, and distribution systems for the crops included in the systems being developed under 4 above. Included are research on marketing channels and institutions required to efficiently (economically and technically) utilize the expected increased output resulting from development of new technology.

6. Conduct research on the national and international trade situation in the crops under consideration, including assistance to national programs in maintaining an ongoing "outlook" analysis and data and analysis for policy makers in the national governments.

7. Assist the national programs in conducting research on the social, income distribution, and other human factors associated with adoption of new technology in the upland crops.

8. Conduct programs which will lead to better control methods of weeds, birds and rodents under Asian conditions.

9. Arrange for Asian scientists (and other leaders and specialists) to come together at regularly held workshops, symposia and conferences at locations where major work is being conducted.

10. Provide for the dissemination of information and research results through a comprehensive series of publications.

11. Training programs as required to assist nations meet manpower needs.

The foregoing is illustrative of the kind of activities the Institute would undertake in support of national programs. In summary, as previously stated, while the exact lines of problem-solving research would depend upon the location of the Institute and the staff assembled, activities should be selected for the prime purpose of generating productivity-increasing technology and demonstrating methodology for the solution of problems impeding agricultural productivity. The problems would be real and, if progress is made, the payoff would be useful technology. The Institute could serve as the world's center for research on sorghum and millets.

Location

Considerations governing the location of the Institute would be those which would facilitate the achievement of objectives. Since the Institute would be to serve national programs in limited-rainfall areas and serve as a world center for sorghum and millets, it follows that the Institute should be located in a suitable agroclimatic zone. Other locational considerations would be those which would favor staffing and operating the Institute. Such things as: a country's interest in assisting and willingness to permit the establishment of the Institute within its boundaries and to recognize and grant international status, including freedom from taxation and permission to move seed and other research materials and information between cooperating countries; facilitating the entry of international students and scientists for training and research; proximity to an international airport, a major city, and to a principal national institution; availability of land and necessary irrigation and utilities; availability of housing, schools and amenities for families of resident scientists, visiting scholars and trainees.

Of special concern would be proximity to a national or state agricultural education and research institution, such as an agricultural university. Closeness to such an institution would promote and facilitate cooperation and positionally favor merging of the institutions when the need for an Asian Upland Crops Institute no longer exists.

Organization

It is recommended that an Asian center for upland crops be established as a non-profit, autonomous, research and training organization with a staff, director and board of trustees. It should have legal status and recognition as an international agency for the public benefit.

The board of trustees should consist of no less than ten and no more than fifteen persons. There should be good balance between expert agricultural scientists, outstanding people in public life, and non-scientists with special interest in the success of the project. Each trustee should serve for a period of three years, with the possibility of reelection. The board would be a self-perpetuating body. It should meet at least once annually at the Institute. There should be three to four representatives from the host country where the Institute would be located, at a level of government sufficient to ensure protection and representation of national interests and participation and cooperation in affairs of the Institute. Similarly, to promote participation, involvement and adequate area and regional representation, there should be representatives on the board from countries the Institute would serve, which would be primarily in the region of location. Completing the board would be representatives of the major donors.

The director should be a distinguished scientist selected by the board and directly responsible to it.

The staff, international in composition, should be selected by the director with the approval of the board.

The functions of the board, director and staff would be elaborated upon the creation of the Institute.

Staff

The problem-oriented programs and activities of the Institute would be conducted by multi-disciplinary teams of scientists. Initially it might be expected that a staff assembled to work on the problems of increasing productivity and real incomes would begin with improving crops and cropping systems, including the use of soil and water. Because of their wide use in limited-rainfall areas, sorghum, millets, wheat, chick-peas and pigeon peas would be singled out for improvement and for use in multiple cropping systems. A senior staff to conduct such programs might be as follows:

Programs	Staff
Administration	Director Deputy Director - Program Assistant Director - International Activities
Crop Improvement: sorghum, millets, chick-peas, pigeon peas	Sorghum Specialist Millets Specialist Pulse Specialist Plant Physiologist
Crop Systems and Other Crops	Interdisciplinary teams; possible assignment of specialists from other research institutes, such as CIMMYT
Soil and Water Use	Agronomist - Cultural Practices/Weed Control Agronomist - Cropping Systems Soil Scientist - Soil Fertility Soil Scientist - Soil Physicist Agricultural Engineer - Farm Machinery Agricultural Engineer - Soil and Water Use Meteorologist

Plant Protection	Plant Pathologist Entomologist
Chemistry	Biochemist/Grain Quality Soil Chemist
Agricultural Economics	Agricultural Economist - with Interdisciplinary teams on Crop Systems and soil and water use
	Agricultural Economist - with Interdisciplinary teams on drying, storage processing and distribution systems
	Agricultural Economist - on marketing channels, distribution, outlook, policy
	Agricultural Economist or other Social Scientist - social, income, human factors and aspects of new technology
Training/Outreach	Communications Specialist Training Officer/Crop Production Specialist

Supported by appropriate numbers of junior scientists, research scholars and student-trainees, the staff would operate in functional groups or teams to resolve major production problems. Work and emphasis on particular problems would ebb and flow with need and circumstances. For example, a major production problem of sorghum is the sorghum shoot fly (Atherigona varia soccata Rhond), an insect pest which severely limits the use of certain high-yielding sorghum hybrids. Conceivably, a team centered around an entomologist, sorghum breeder, and an agronomist working in close cooperation with scientists in interested nations would make reasonable progress in developing resistant varieties, materials and production procedures to reduce and/or eliminate the problem of the sorghum shoot fly. Experience has shown that most crop production problems eventually yield to a concerted, systems-type research effort.

The composition of problem teams would vary depending on the problem. Such a team-problem-oriented organization would build program flexibility into the staff organization and permit program shifts and changes to meet changing research needs. Additionally, such an organization would facilitate allocation of men, money, materials and time to functional activities, thereby ensuring, perhaps, better administrative and financial identification and control over programs and staff activities.

Social and economic problems which (a) are present because new technology is not yet available in limited-rainfall areas; (b) will need to be solved before the new technology that is created will be adopted; and (c) in turn result from the adoption of new technology; would receive attention from the start of the Institute. Such research would be within the context of the team-problem-oriented organization of the Institute. Special emphasis would be on Institute senior staff working with colleagues in the nations in the area served by the Institute, with a view to developing capabilities for maintaining viable research programs in these nations. The underlying philosophy is that social and economic problems in limited-rainfall areas of Asia will in the long run have to be solved by Asians.

To ensure and facilitate rapid exchange of information and materials, mutual support, and attention to major problems, constant contact and liaison would be maintained with other centers of work.

Physical Facilities

Until programs and staffing plans are projected precisely, it would be unrealistic to attempt precise estimates of requirements for land, buildings and equipment. From experience gained in developing existing international institutes, the requirements are apt to be substantial.

Sufficient land of suitable character will be required for experimental plots; seed multiplication fields; training and demonstration areas; administration, laboratory, and service buildings, including greenhouses; and, perhaps, residential and recreational areas for staff. The latter will depend upon local availability of housing and public services.

Land availability at existing international institutes ranges from 106 acres at CIMMYT to 2200 acres at IITA (CIMMYT carries out a significant portion of its program at experiment stations provided by the Mexican Ministry of Agriculture). CIAT in Colombia is constructing its headquarters on a 1200-acre site near Palmira. IRRI has close to 200 acres for field experimental work in addition to administration, service and residential areas. Thus, there are wide differences in the amounts of land used and controlled by the several international institutes. The nature of programs likely to be undertaken by an institute working on the problems of limited-rainfall agriculture would suggest a size of the order of 400-500 acres.

Estimated Cost

It would be unrealistic to project other than in general terms on capital and operating costs. Based on the experience of other international centers and considering rising costs, capital costs are likely to be in the $12-15 million range. Whether land would be provided by the host government or have to be purchased will be an important element of the total capital requirement.

Capital costs for the establishment of IRRI and IITA have been approximately $7.5 million and $12.0 million, respectively, exclusive of lands which were provided by host governments. Expansion of facilities and services since establishment has increased these costs. In the case of IITA, capital costs are approaching $16.0 million and are apt to reach $20.0 million.

Operating costs for an upland crops center would likely reach $1.5 million to $2.0 million-plus annually. IRRI's operating budget, which reflects a large staff and a wide range of training and other support services, is a bit over $2.0 million. In the case of IITA, still in the process of developing a range of services, the operating budget is about $1.5 million.

Financing

Funding of capital and annual operating costs might be provided from a number of agencies having an interest in the work of the Institute.

APPENDIX 10

IMPORTANT CROPS GROWN IN THE TROPICS

Cereals

Rice (*Oryza sativa*)

Sorghum (*Sorghum vulgare*)

Millets

Pearl Millet or Bajra (*Pennisetum typhoides*)

Finger Millet or Ragi (*Eleusine coracana*)

Maize (*Zea mays*)

Wheat (*Triticum aestivum* and *T. durum*)

Food Legumes

Mung Bean (*Phaseolus aureus*)

Haricot Bean or Kidney (*Phaseolus vulgaris*)

Black Gram or Urd (*Phaseolus mungo*)

Pigeon Peas (*Cajanus cajan*)

Cowpeas (*Vigna sinensis*)

Soybeans (*Glycine max*)

Chick-pea or Garbanzos (*Cicer aurietinum*)

Peanuts (*Arachis hypogaea*)

Roots/Tubers

Potato (*Solanum tuberosum*)

Cassava (*Manihot esculenta*, *M. utilissima*)

Sweet Potato (*Impomoea batatus*)

Yams (*Discorea alata*)

Dasheen or Taro (*Colocasia esculenta*)

Fibers

Cotton (*Gossypium arboreum*, *G. herbaceum*,
G. barbadense, *G. hirsutum*)
Jute (*Corchorus capsularis*)
Abaca or Manila Hemp (*Musa textilis*)
Sisal (*Agave sisalana*)

Sugar

Sugarcane (*Saccharum officinarum*)

Oilcrops

Castor Bean (*Ricinus communis*)
Groundnut (*Arachis hypogaea*)
Oil Palm (Various *Palmaceae*)
Soybean (*Glycine max*)
Sesame (*Seamum indicum*)
Coconut (*Cocos nucifera*)

Others

Coffee (*Coffea arabica*, *C. robusta*)
Tea (*Thea sinensis*)
Cacao (*Theobroma cacao*)
Tobacco (*Nicotiana tabaccum*)
Spices and Flavoring Oils
Tropical Fruits
Tropical Vegetables